Risk, Performance and Uncertainty in the Geological Storage of CO_2

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Summary

The risks associated with the geological storage of CO_2 are a key factor affecting the implementation of carbon capture and storage. A better understanding and quantification of these risks is required to ensure risks associated with CO_2 storage in underground formations meets acceptable safety standards. Substantial research is currently underway worldwide on risk assessment methodologies for the geological storage of CO_2. There is however, some confusion regarding the definition of risk assessment, performance assessment and uncertainty assessment in these applications. Understanding how these terms are being applied to geological storage projects will ensure a minimum of confusion will arise when large scale demonstration projects undergo regulatory and international review.

Introduction

CO_2 capture and storage in geological formations is now establishing itself as a technical option that has the potential, when used in conjunction with other mitigation options[1], to make deep reductions in atmospheric emissions of CO_2. There are now a number of commercial scale projects, either underway or in the planning stage, that capture CO_2 emitted from gas processing operations and store the CO_2 in geological formations. In addition, CO_2 is routinely injected into geological formations in North America as part of enhanced oil recovery operations. However, operations, such as those described above, are only storing a small proportion of the CO_2 emissions that will have to be avoided if the UNFCC[2] goal of 'stabilization of atmospheric concentrations of greenhouse gases' is to be achieved. To achieve this goal substantial deployment of CO_2 capture and storage (CCS) technology will be required across the globe. Such a widespread deployment of technology will mean that policy makers and the general public will need to be fully supportive of the technology.

One key element of this widespread deployment and public acceptance is the issue of risk assessment. It will be fundamental component to delivering carbon capture and storage as a means of reducing emissions of CO2 from fossil fuel use. Current world concern around climate change is forcing government to act on emissions reductions and geological storage, if fully accepted by the public and regulators will be a key component in allowing the continued use of fossil fuels. *Storing quantities of* CO_2 *in Alberta's geological formations rather than releasing it to the atmosphere* is identified as one of the three action platforms in Alberta's 2008 Climate Change Strategy. Risk assessment is, in a sense, the route to fully understanding the

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[1] Other mitigation options can include: energy efficiency improvements, fuel switching and use of renewable energy
[2] United Nations Framework Convention on Climate Change

implications of storage as well as the route to gaining acceptance of its integrity. As such, risk assessment allows for:

- Public acceptance of geological storage of CO_2 and the confidence that storage is one of the effective responses to continued fossil fuel use.
- Licensing of storage sites for use by industry, including the development of Environmental Impact Assessments.
- Understanding the implications of transfer of long-term liability by the public sector and its acceptance by the regulator.
- Determining effective MMV programs required for different site types and for ensuring verification of CO_2 inventories.

A rational framework is required for integrating the technical elements of risk assessment and the requirements deemed necessary for workable or viable quantification protocols. It is postulated that the protocols will provide a mix of prescriptive and performance related targets that must be met by geological storage projects in order to generate sufficient verification information to allow storage integrity to be certified and credits to be given. Elements of the risk assessment framework that will require the attention of the geoscience community will entail the following activities:

- Issues surrounding risk quantification in the face of the uncertainty inherent when dealing with natural systems;
- Placing performance/risk assessment within existing, well-defined frameworks that are acceptable and familiar to industry, such as the hazards and effects management process;
- Developing decision support tools to complement risk assessment and monitoring information collection;
- Develop probabilistic tools for assessing the risk associated with CO_2 storage ;
- Long-term performance assessment to improve our understanding of the long-term implications of storage through to full dissolution of the CO_2 in reservoir fluids;
- Risk quantification - risk is unlikely to be truly quantifiable, but techniques can be used to attain some quantification based on assumptions about uncertainty;
- Model simplification (modeling within a "bow-tie" or similar framework); and
- Life cycle analysis (particularly development of subsurface project boundaries, decision support systems).

The list described above is not uncommon and are topics found in many if not most publications discussing risk assessment. It is worthy to note that the above list contains elements of risk, performance and uncertainty elements within the realm of CCGS. In its purest sense, risk is evaluated as the combination of consequence and likelihood, as illustrated in Figure 1, and represents something more substantive than just hazard assessment and moves well beyond quantitative statements of (storage) system performance.

To gain public acceptance of CCS the regulators and public will also need to have confidence in the effectiveness of risk assessment predictions. To gain such confidence it will be necessary to benchmark the different approaches[3] being used, in an open and transparent manner, so that the results are understood and the implications of the results for ecosystems and human health can be fully appreciated. Risk management provides a comprehensive decision-making process that aids decision-makers in identifying, analyzing, evaluating and controlling all types of risks, including risks to health and safety. The objective of risk management is to ensure that significant risks are identified and that appropriate action is taken to minimize these risks

[3] Risk Assessment approaches that are being developed include: semi-quantitative and quantitative methods, deterministic and probabilistic techniques.

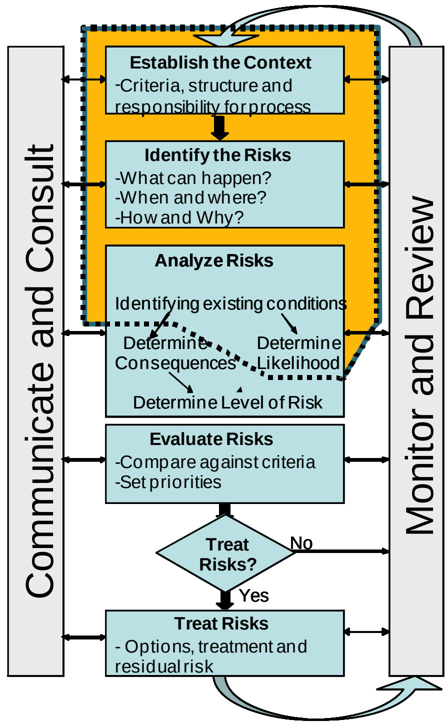

Figure 1: Risk management process including risk assessment and risk analysis

Regardless of the level of effort in site characterization, a level of uncertainty will always exist in our understanding of the subsurface and for the geological storage of CO_2, uncertainty in long-term effects or storage processes. Uncertainty management plans are commonplace in the oil and gas industry. The plans are intended to identify all of the subsurface risks; evaluate the impact of each uncertainty; generate options for managing the subsurface risks; develop and implement monitoring plans to identify if an unexpected outcome occurs, and; manage these unexpected outcomes. With reference to subsurface projects, such as CCGS, these plans document subsurface uncertainties, develop work plans to better understand and resolve the identified uncertainties, and perhaps most critically, plans for managing these uncertainties in the future. For example, key subsurface technical uncertainties for CCGS will likely include CO_2 injectivity, pore pressure increases due to CO_2 injection, degree of heterogeneity with the injection horizon, containment risk associated with existing and new wellbores, etc.